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# WATERTOWN ARSENAL LABORATORY

## MEMORANDUM REPORT

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INVESTIGATION OF SUB-SIZED CHARPY SPECIMENS

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INVESTIGATION OF SUB-SIZED CHARPY SPECIMENS

Abstract

Frequently it is necessary to determine the toughness of steels made into very thin sections. To develop a means of testing such steels, two types of sub-sized specimens were investigated. In one series, all dimensions were reduced proportionately. In the other, the width was increased as the thickness and the notch depth and radius were made smaller. The smaller specimens in both cases showed lower transition temperatures than the larger specimens. Even when all dimensions are decreased only by 1/2 that of the standard (the area decreased to 1/4), the difference in energy between ductile and brittle steels is so small as to make comparison difficult. With a small impact machine the energy can, however, be measured more accurately. A specimen of 1/2 the thickness and twice the width of the standard can be used advantageously. Even thinner specimens could be used if the width was made proportionately greater.

Introduction

Recently, the trend in gun design has been toward thin high strength tubes. It is frequently necessary to determine the toughness of the steels from which such tubes are made. With this in mind, the Gun Steel Branch of the Watertown Arsenal Laboratory requested the Physical Metallurgy Section to perform a few experiments with sub-sized Charpy specimens, so as to indicate whether they could be used to measure the toughness of steel in thin sections. This report describes the results of these experiments.

In order to determine the toughness of steel from thin gun tubes, the thickness of the specimens must be less than that of the standard "V" notched specimens. It is generally believed that, as the size of impact specimens are reduced while maintaining similitude, the conditions of the test become less severe; i.e., the temperature of brittle failure decreases. Thus, for the present investigation, it was decided that two series of specimens could be studied advantageously. In one series all dimensions were decreased proportionally. In another, the width of the specimens was increased as the thickness, notch depth, and notch radius were decreased.

By increasing the width, the transverse constraint is increased slightly and the cross sectional area of the specimen can be maintained. Thus, the conditions of the test are slightly more severe and the energy to break ductile specimens higher than if all dimensions are reduced proportionately.

### Materials

The materials used in this investigation were:

- 1). S.A.E. 1020 hot rolled bar stock; Rockwell "B" 65.5-66.5.
- 2). S.A.E. 3130 bar stock.
- 3). A section near one end of a large forging (Steel No. 1033).

The compositions of the steels were as follows:

<u>Material</u>	<u>C</u>	<u>Mn</u>	<u>P</u>	<u>S</u>	<u>Si</u>	<u>Cr</u>	<u>Ni</u>	<u>Mo</u>	<u>V</u>
SAE 1020	.20	.49	.011	.033	.22	--	--	--	--
SAE 3130	.33	.86	.026	.019	.22	.49	1.20	trace	Nil.
No. 1033	.32	.69	.021	.021	.24	.84	3.47	-.34	.06

Since the 1020 bar stock was 2 inches in diameter, four longitudinal Charpy specimens were machined from the cross section as shown in Figure 1. In all cases, regardless of the size of the specimen, the center of the height of the Charpy specimen was 5/8 of an inch from the center of the bar, thus all specimens were machined from near the same relative position in the bar stock.

For heat treatment purposes the 5/8 inch diameter S.A.E. 3130 steel bar was cut into five-inch lengths with two Charpy specimens being machined from each five-inch length after heat treatment. Half of the bars were quenched and tempered, whereas the remainder were quenched, tempered, and embrittled. The heat treatment which the S.A.E. 3130 bars received is given below.

	<u>Non-Embrittled</u>	<u>Embrittled</u>
Austenitize	1625° F., 1 hour	1625° F., 1 hour
Quench	Water	Water
Temper	1100° F., 1 hour	1100° F., 1 hour
Embrittle		850° F., 50 hours

All specimens were water quenched following tempering and embrittling. Hardness of both sets was in the range of Rockwell "C" 26-27. The non-embrittled bars were marked "Z" and the embrittled bars marked "X".

The details of the heat treatment of the forging are not known.

This material was used in this investigation without receiving any additional heat treatment.

Figure 2 lists the types of specimens machined from the three steels used in this study. For the specimens of S.A.E. 1020 and forging No. 1033, the width was increased as the thickness decreased so as to maintain a constant cross-sectional area of the specimens. With the thinnest specimens, it was not believed feasible to follow this procedure for the specimens would have been an inch and a half wide. This extreme width was not believed to be practical. Thus, the width of the specimens having a thickness of .099" is the same as that of the specimens having a .197" thickness. Difficulty was encountered in machining the .0025 radius at the bottom of the notch of the steel 1033. However, the radius never exceeded .003.

### Tests and Results

All specimens, with the exception of the .197" square specimens from the 3130 steel tested at -20° C. and below, were broken on the standard Charpy machine. The other .197" square specimens were broken on the 16 ft.-lb. Charpy machine. Tables I, II, and III list the energy absorbed, types of fracture, and temperature of tests for all specimens. In Figures 3, 4, and 5, these results are plotted.

### Discussion

The data indicate that only for the thinnest specimens of the three steels was the transition temperature from ductile to brittle failure appreciably lower than that of standard specimens. In the case of the 3130 steel (all dimensions reduced), the 1/2 size specimen showed an appreciably lower transition temperature than did the standard specimens. For the other steels using the wider specimens, the effect is clearly noticeable only with the 1/4 thickness specimens. Thus, large reductions in the size of the specimens does decrease slightly the severity of the notched-bar test. Possibly, if all dimensions were scaled, including those of the testing machine, the effect would not be as great.

An examination of the fractures described in Tables I, II, and III also indicate that the tests with the smaller bars are less severe. The fracture rating can be used to distinguish between ductile and brittle material.

In Figures 6 and 7, the relation between the energy of the standard and sub-sized specimens of both types are plotted (from the meagre data of Figures 3, 4, and 5). In these figures only the values are taken from tests above the transition zone, for only in this case are the energies correlatable. The figures indicate that, for the specimens in which all dimen-

sions were reduced, the 1/2 sized specimens would have only about 8 ft.-lbs. energy when the standard specimen revealed 40 ft.-lbs. Satisfactory and unsatisfactory metal would necessarily fail in the range of from 1 to 8 ft.-lbs. (for 40 ft.-lbs. standard energy). If the small impact machine is used, the errors should be reduced and differences within this range might be almost as readily determined as with a wider range of values obtained on the large machine with large specimens.

For the wider specimens the 1/2 thickness specimens would require about 28 ft.-lbs. when the standard Charpy was 40 ft.-lbs. The 1/4 thickness specimen would require about 12 ft.-lbs. The wide 1/2 thickness specimen could definitely be used to distinguish steels of different structures.

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TABLE I

## IMPACT RESULTS FOR S.A.E. 1020 STEEL

Temp. of Test (° C.)	STANDARD		3/4 THICKNESS		1/2 THICKNESS		1/4 THICKNESS	
	Mark	Ft.-Lbs. Frac.	Mark	Ft.-Lbs. Frac.	Mark	Ft.-Lbs. Frac.	Mark	Ft.-Lbs. Frac.
-78	K1	1.6 Cb	L1	1.2 Cb	M1	1.6 Cb	N1	1.2 Cb
-60	K2	3.3 Cb	L2	3.1 Cb	M2	3.3 Cb	N2	2.1 Cb
-40	K3	5.3 Cb	L3	4.1 Cb	M3	5.1 Cb	N3	4.1 Cb
-20	K4	6.4 Cb	L4	7.2 Cb	M4	7.7 Cbf 7/8	N4	10.9 Cbf 3/4
-10	K5	9.7 Cb	L5	13.3 Cbf 7/8	M5	14.2 Cbf 4/5	N5	13.0 Cbf 1/2
0	K6	26.5 Cbf 7/8	L6	28.0 Cbf 4/5	M6	15.5 Cbf 4/5	N6	14.2 Cbf 1/2
+20	K7	60.5 Cbf 3/4	L7	49.6 Cbf 1/3	M7	41.5 Cbf 1/2	N7	17.1 Fc

F = Fibrous

Fc = Fibrous and Spots of Crystalline

Cb = Bright Crystalline

Cbf = Bright Crystalline (Fibrous Border)

Fractions represent amount of Crystalline area.

TABLE II

## IMPACT RESULTS FOR STEEL NO. 1033

Temp. of Test (° C.)	STANDARD		3/4 THICKNESS		1/2 THICKNESS		1/4 THICKNESS	
	Mark	Ft.-lbs. Frac.	Mark	Ft.-lbs. Frac.	Mark	Ft.-lbs. Frac.	Mark	Ft.-lbs. Frac.
-78	A1	13.8	Cdf 7/8'	C1 14.5	Cdf 3/4'	E1 11.8	Cdf 7/8'	G1 5.8
-60	A2	20.4	Cdf 4/5'	C2 20.8	Cdf 3/4'	E2 18.7	Cdf 2/3'	G2 8.3
-40	A3	24.3	Cdf 2/3'	C3 25.0	Cdf 2/3'	E3 20.8	Cdf 1/2'	G3 11.8
-20	A4	34.2	Cdf 1/4'	C4 31.8	Cdf 1/5'	E4 29.1	Fc	G4 11.4
0	A5	43.2	Fc	C5 38.6	Fc	E5 30.7	Fc	G5 12.1
+20	A6	46.6	Fc	C6 41.1	Fc	E6 32.6	F	G6 12.4

F = Fibrous

Fc = Fibrous and Spots of Crystalline

Cdf = Dull Crystalline (Fibrous Border)

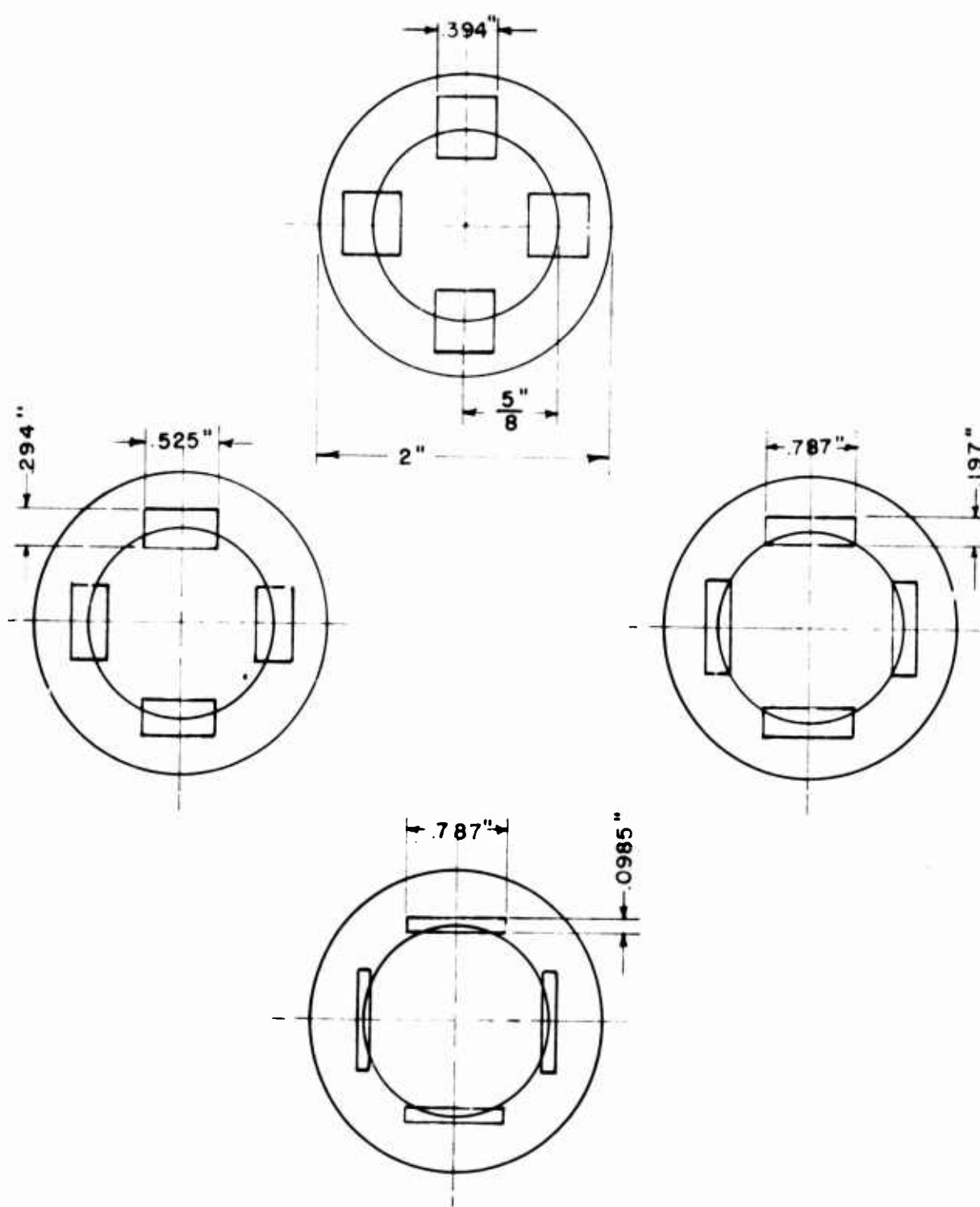
Fractions represent amount of Crystalline area.

IMPACT RESULTS FOR S.A.E. 3130 STEEL

F = Fibrous  
Cd = Dull Crystalline

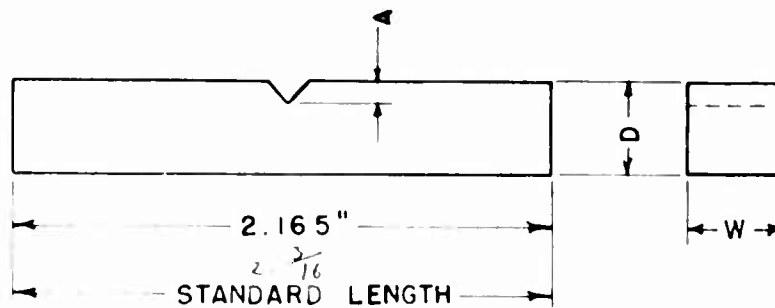
Cdf = Dull Crystalline with Fibrous Border  
Fractions represent amount of Crystalline area.





LAYOUT OF SPECIMENS FROM SAE 1020 BAR STOCK

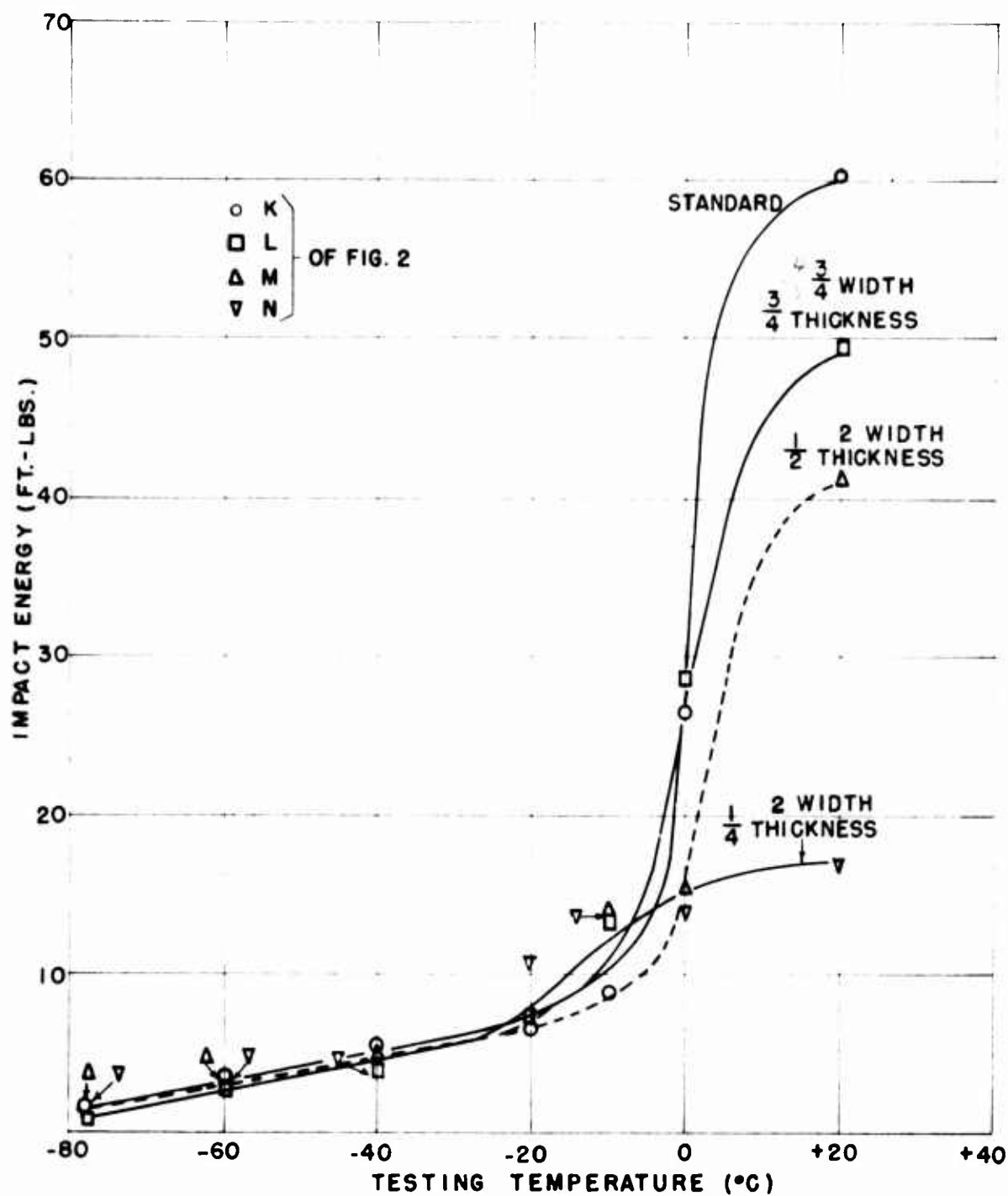
FIG. 1



MATERIAL	MARK	W	D	A	RADIUS AT BASE OF NOTCH
1020	K	.394	.394	.078	.010
1020	L	.525	.294	.0585	.0075
1020	M	.787	.197	.039	.005
1020	N	.787	.099	.0195	.0025
3130	X-1 TO X-10 Z-1 TO Z-10	.394	.394	.078	.010
3130	X-13 TO X-22 Z-13 TO Z-22	.294	.294	.039	.005
3130	X-25 TO X-34 Z-25 TO Z-34	.197	.197	.0195	.0025
1033	A	.394	.394	.078	.010
1033	C	.525	.294	.0585	.0075
1033	E	.787	.197	.039	.005
1033	G	.787	.099	.0195	.0025

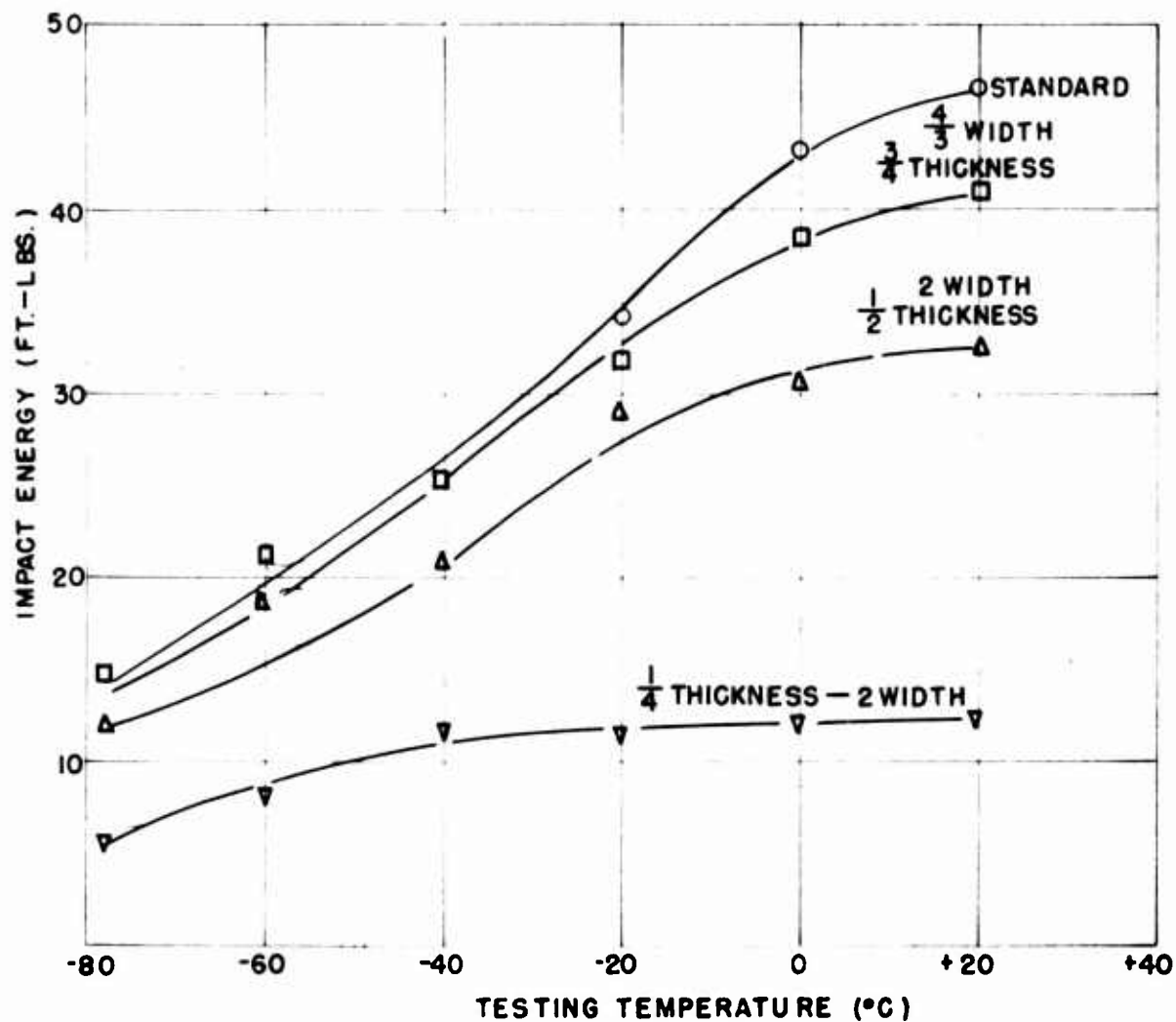
TYPES OF SPECIMENS USED  
FOR BOTH STEELS

FIG. 2



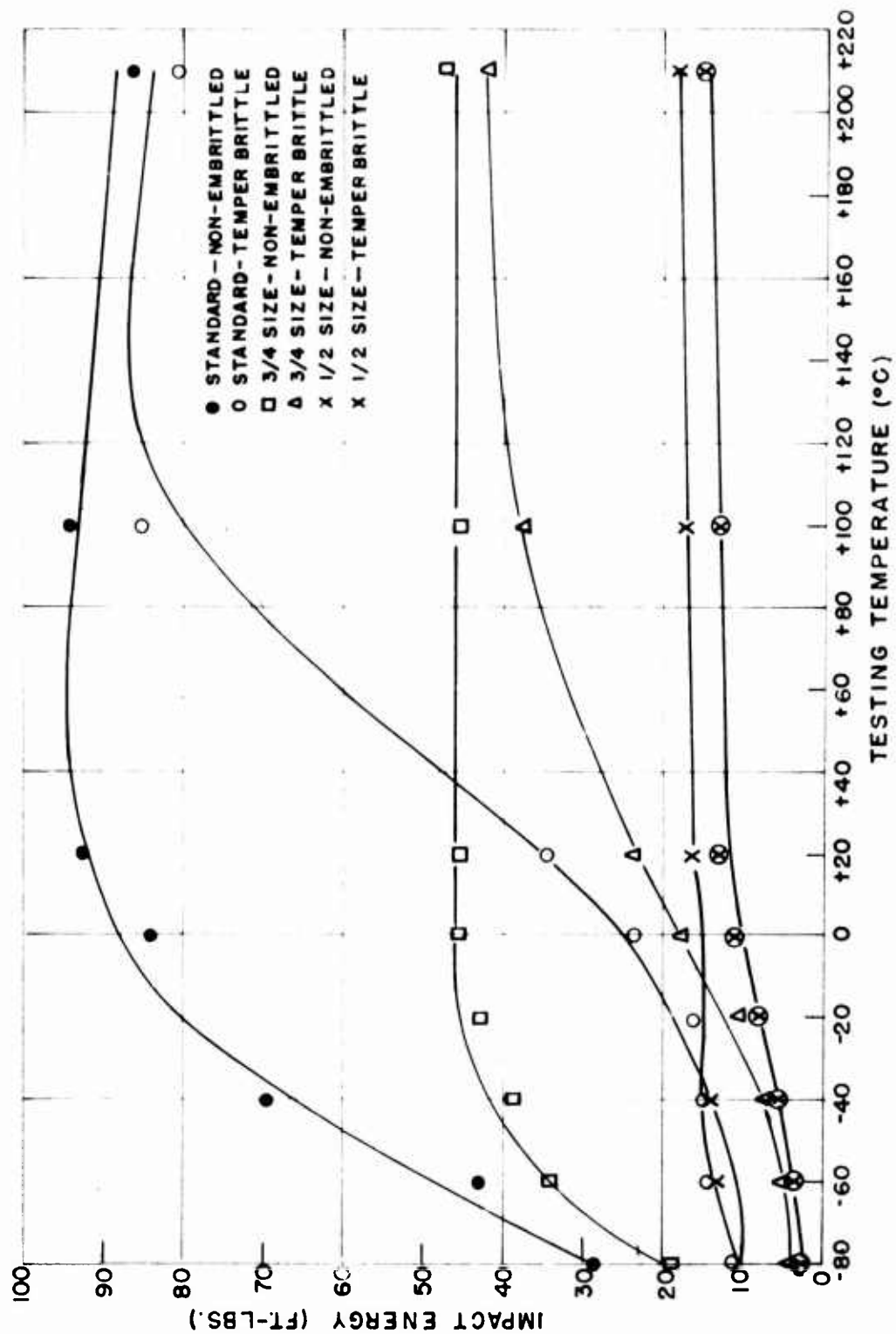
IMPACT RESULTS OF STANDARD & SUBSIZE SPECIMENS  
OF SAE 1020 STEEL.

FIG. 3



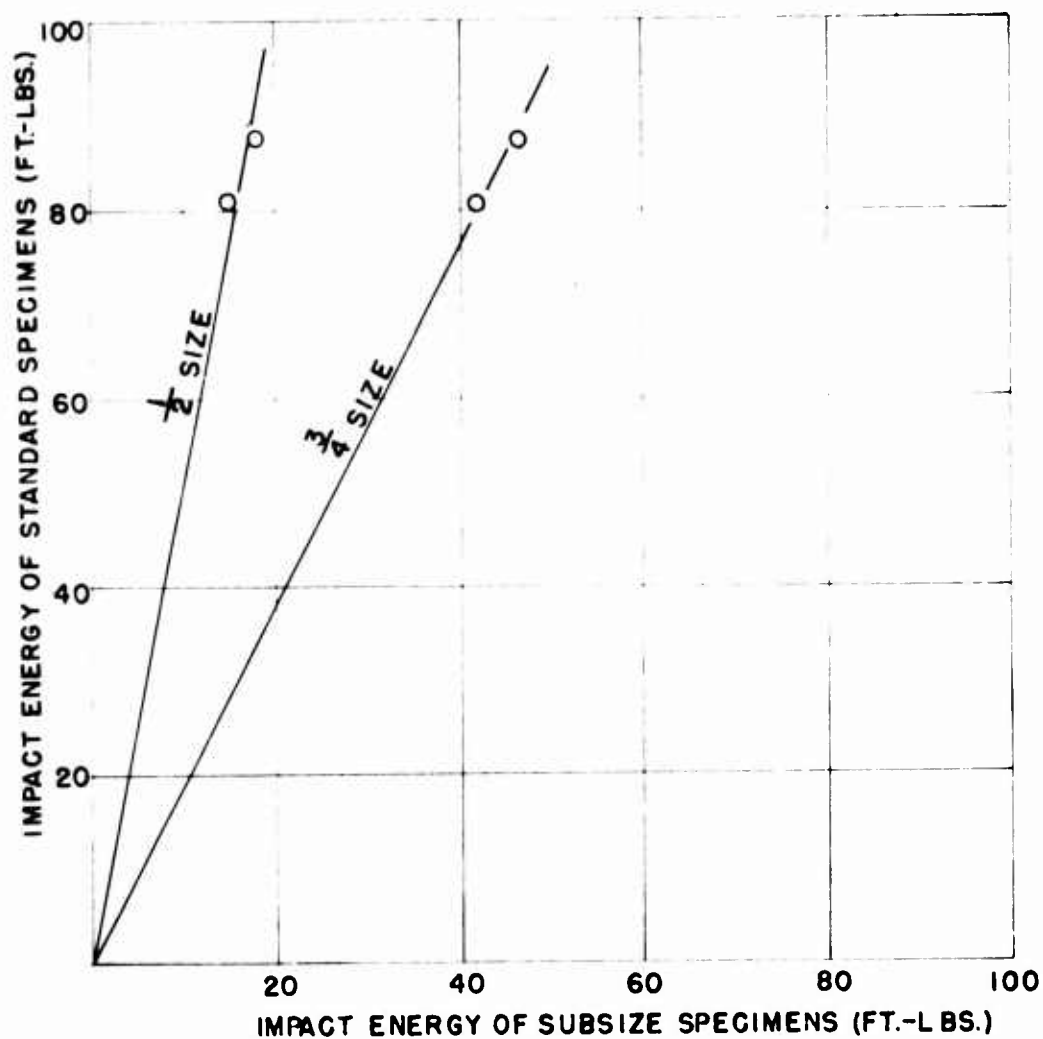
IMPACT ENERGY OF STANDARD & SUBSIZE SPECIMENS OF  
OF STEEL NO. 1033

FIG. 4



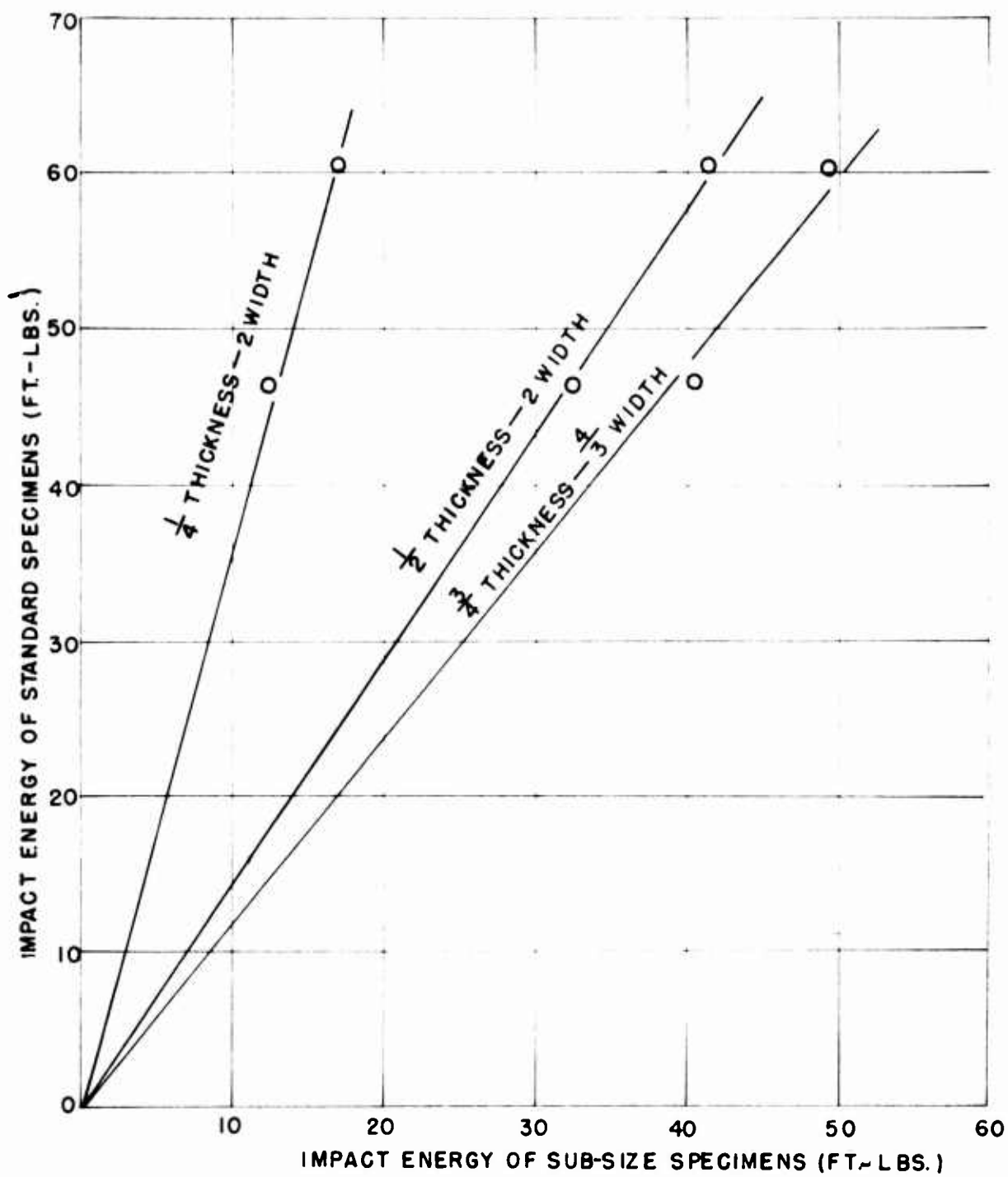
STANDARD & SUB-SIZE - REGULAR & TEMPER BRITTLE IMPACT ENERGY  
OF SAE 3130 STEEL.

FIG. 5



APPROXIMATE RELATION BETWEEN ENERGY OF  
STANDARD & SUBSIZE SPECIMENS (ALL DIM-  
ENSIONS REDUCED).

FIG. 6



APPROXIMATE RELATION BETWEEN ENERGY OF STANDARD & SUB-SIZE SPECIMENS. (ALL DIMENSIONS REDUCED EXCEPT WIDTH).

FIG. 7